

Brass Tacks

An in-depth look at a radio-related topic



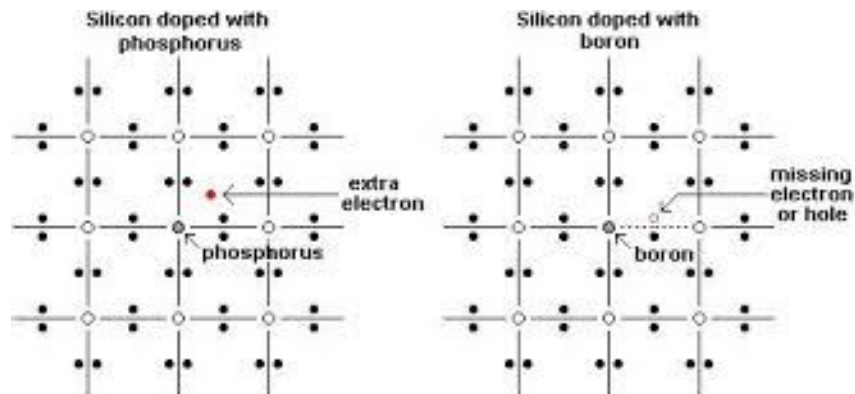
Solar power

Every day, more and more people turn to the Sun as this seemingly limitless energy source that freely shines down upon us. Whether it's by solar panels on our roofs or through a tiny film on a calculator, we're taking advantage of technology that allows us to convert *radiant energy* into *electrical energy*. Let's address exactly how that conversion takes place.



A solar cell starts out as two slices of ordinary silicon, a good insulator in its pure form, but made with an impurity mixed in, a process known as *doping*.

One of the impurities is phosphorus, creating an **n-type** material, meaning the chemical bond between silicon and phosphorus results in an *extra electron* in the substance per phosphorus atom. The other impurity is boron, creating a **p-type** material, meaning the bond between silicon and boron results in a *missing electron* in the substance per boron atom.



These impurities turn the otherwise pure silicon insulators into fair conductors (called *semiconductors*), and are not all that remarkable by themselves. But bringing the two pieces of differently doped silicon in contact with each other produces an electronic arrangement such that electrons can flow through the two conductors, from the n-type side (**cathode**) through the border (called the **P-N junction**) between them, to the p-type side (**anode**), *but not in the other direction*, due to the polarized electric field created by the junction. This is known as a *semiconductor diode*.

So, a solar cell is not much more than an ordinary diode, but necessarily so, to favor a current flow in one direction, like a battery. Without this diode effect, the electrons would diffuse in both directions, neutralizing the current flow. (Also, keep in mind that the direction of *current flow* is the same as that for *hole flow*, and is opposite the direction of *electron flow*.)

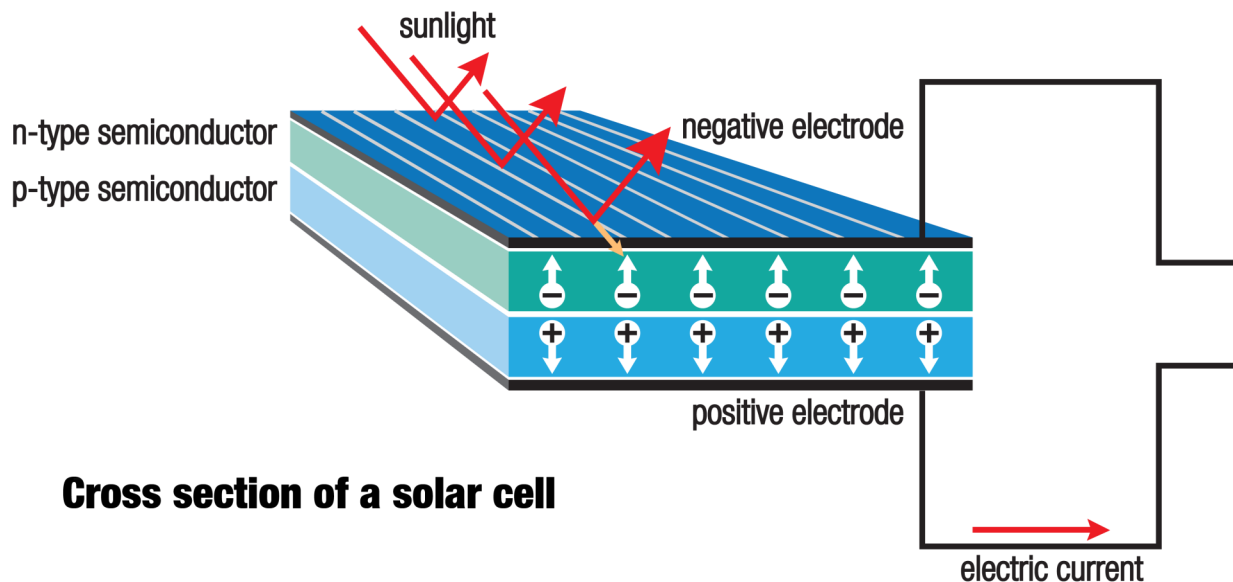


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When sunlight strikes the n-type surface, the energy of the photons can be great enough to cause an electron in the phosphorus valence band to absorb the radiant energy and jump to the conduction band and become free to move about (the sunlight knocks it loose, to allow for electron flow). Because of the electric field imposed by the potential difference across the P-N junction, the freed electron rushes toward the p-type side (and holes toward the n-type side), where it accumulates with others, and presents an external charge pressure (voltage) to its external metallic electrodes, by electrons on one and holes on the other.



Cross section of a solar cell

This is known as a *photodiode*, or a *light-absorbing diode*, and the process described is known as the **photovoltaic effect**. If you then wire a closed resistive circuit across the electrodes of the two sides, a current will flow through the photodiode when it's exposed to sunlight. Couple several solar cells together electrically to form a **solar panel** or solar module. A **solar array** is a set of solar panels you might find on a building. It's important to note that, without



solar cell



solar array or panel array

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the circuit to form an electrical path between the anode and cathode, there's no place for the electrons to go, and the solar cell will simply receive the light without performing any of the conversion.

Efficiency

Capturing and converting more of the Sun's rays is an ongoing development struggle, and where much of the current research is focused. One problem is the unused light that's reflected off the solar cell surface. Another is the heat generated by light absorption. It turns out that some of the heat actually aids the conversion process, but the majority is wasted. So, just how much radiant energy is converted to electrical energy? Depends on the solar cell technology.

At the time of this writing, about 10% of the solar market uses **thin film** solar cells, which are less than 20% efficient, meaning for every five buckets of sunlight poured onto a thin film solar cell, under one bucket of electricity will be produced. (I forget right off what the conversion factor is, from buckets to kWh, but I digress.) Over 50% of the current market uses **polycrystalline** solar cells, which are about 20% efficient. About 33% of the current market uses **monocrystalline** cells, which are of slightly newer technology, and about 23% efficient.

Power management

One of the primary problems encountered when using solar panels is the wide range in voltage presented by a solar cell, due primarily to the proportion of sunlight exposure. Obviously, your panel can produce more power when it's exposed to direct, bright sunlight, than during cloudy or dimly lit hours. A device called a **charge controller** is essential to almost any solar-powered solution, and can provide a steady voltage over a wide range of available light. More generally, the purpose of a charge controller is to **manage power** in a solar setup.



Unlike with a solar-powered calculator, most solar solutions involve the **storage** of energy, to allow a supplied device to continue running, even after dark. For this, you'll need a **battery**, and one that can be charged daily and withstand a fairly large amount of energy depletion (more on this later). In spite of the battery variety available for solar power, a charge controller can perform many necessary functions involved with energy storage.

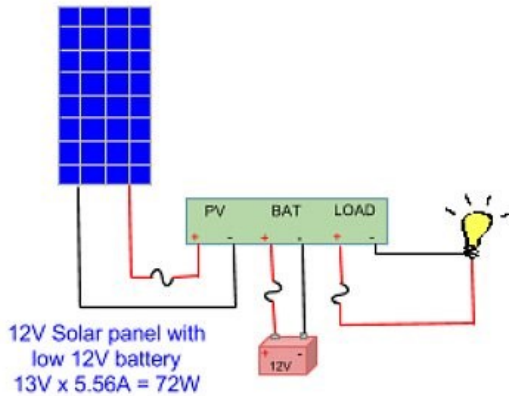
A charge controller should be able to a) charge a battery while running a device, b) charge a battery while running no device, c) sense the amount of stored energy currently in a battery and adjust its supply to the battery as needed, and d) prevent depletion of the battery by the solar cells during dimly lit moments. In general, there are two kinds of solar charge controllers on the market today that perform these tasks: PWM (pulse-width modulation) controllers and MPPT (maximum power point tracking) controllers.

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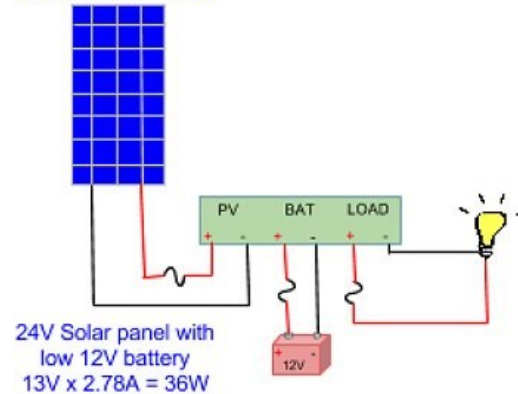
12V Solar panel potential
 $18V \times 5.56A = 100W$



12V Solar Panel with PWM charge controller
 charging a low 12V battery

28% loss

24V Solar panel potential
 $36V \times 2.78A = 100W$

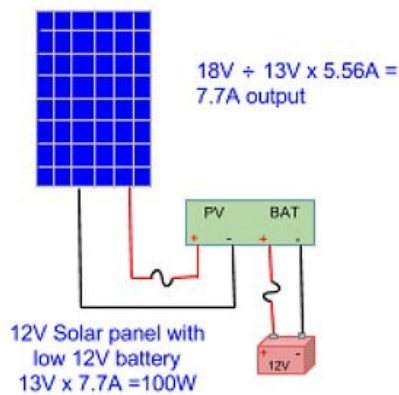


24V solar panel with PWM charge controller
 charging a low 12V battery

64% loss

PWM charge controllers are typically lower in cost than MPPT charge controllers, but they tend to incur heavy power losses when the solar panel output does not match the nominal battery voltage. MPPT charge controllers are typically much more expensive than PWM charge controllers, but incur very little power loss, whether or not the panel output matches the battery voltage, and can often make up for the cost difference in power savings. If you can afford one, I highly recommend using an MPPT-type charge controller for your solar needs.

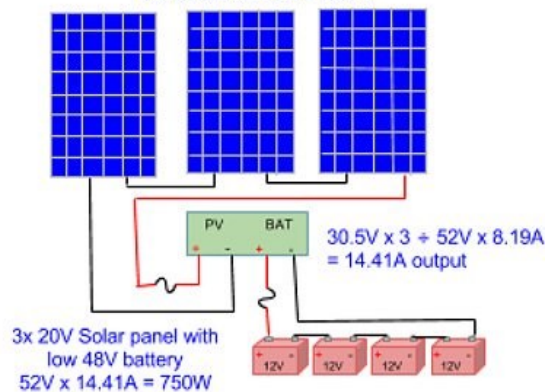
12V Solar panel potential
 $18V \times 5.56A = 100W$



12V Solar Panel with MPPT charge controller
 charging a low 12V battery

Virtually no loss

Three 20V Solar panels in series for 60V
 $3 \times 30.5V \times 8.19A = 750W$



Three 20V Solar Panels in series with MPPT
 charge controller charging a low 48V battery

Virtually no loss

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Energy storage

Once you've successfully converted and controlled all that free solar energy, you'll need to store it, to ensure that energy will be available to you after dark. As mentioned, this storage is normally available in the form of a battery, but not just any battery. Of course, the battery intended for solar energy storage needs to be *rechargeable*, but also **deep-cycle**, meaning it should be able to handle a large depletion of its stored energy without damage to the battery.

There are other battery factors to consider, such as nominal (the named) voltage, capacity (number of Ah), content (lead-acid, lithium, AGM, etc.), depth-of-discharge, and more, but we'll save our exploration into these different parameters for another article. Meanwhile, let's agree on a few battery semantics, to make sure you and I are speaking the same language.

First, the word **charge** is a little confusing. When we use it as a verb, as in, "I want to charge my battery," or "My battery is fully charged," that's appropriate, because it means **store energy in**, or in other words, *energize*. But using it as a noun is where it gets confusing, as in "My battery stores charge," or "The controller sends charge to my battery." This is because, as long as your battery doesn't gain or lose any chemicals, *it will always contain the same amount of charge, whether it's fully energized or completely dead*.

Second, batteries work by chemical reaction, so that one chemical reacts with a metal (called the **anode**, or negative "−" terminal), and *produces* electrons as a reaction by-product. If there's no place for the electrons to go, the reaction can only take place up to a point of equilibrium. Meanwhile, another chemical reacts with another metal (called the **cathode**, or positive "+" terminal), and *requires* electrons for its reaction to complete. If nothing provides electrons to complete the reaction, the reaction cannot take place there, until the electrons are provided.

Third, if we now compare the amount of potential (possible) electron stream *available* at the anode, with the amount of potential electron stream *needed* at the cathode, we call the difference between the two potentials **voltage**. Indeed, it's more technically accurate for us to say that the battery stores *potential energy*, rather than saying that it stores *electrical energy*. However, in the interest of brevity, I'll just say that the battery **stores energy**, and you'll know what I mean. (Also, I'll not attempt to distinguish between a battery and a **cell** here.)



Using the battery

If we provide a pathway (wire, circuit, etc.) for the electrons in the anode reaction to flow to the cathode reaction, both reactions can readily take place, and we now have **direct current** (DC) flow though the pathway, from the cathode side, through the pathway, and into the anode side. If the battery chemical reactions are reversible, we call that a **rechargeable battery**; if they are not reversible, it's a one-life, non-rechargeable battery, to be discarded after most of the chemicals have reacted to present an acceptable voltage level.

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Now, let's replace the pathway with our solar cell, the subject of this article. If we connect the solar cell anode with the rechargeable battery anode (and therefore, cathode to cathode), and the potential (voltage) presented by the solar cell is greater than that of the battery, then expose the solar cell to sunlight, current will flow out the cathode of the solar cell and into the cathode of the battery, reversing the chemical reactions and effectively **recharging** the battery. But that flow needs to be carefully controlled; hence, the need for the charge controller.

Calculating solar power needs

Knowing just how much solar power you'll need will require some fair estimation, and might even include some predictions of your future needs. On one hand, you can power your entire home with a large solar array and a battery bank to match. On the other hand, since this newsletter is geared toward amateur radio, let's concentrate on that one aspect. To illustrate how to calculate your needs, I'll present two radio-related situations, mobile and portable HF, including an inefficient inverter for a laptop.

Electrical needs common to both

- laptop (Chromebook charger and [inverter](#) = 6.6 A » 6.6 Ah)
- cell phone charger (12 V to USB = 3 A » 3 Ah)
- lighting ([PWRbrite LED Light Strip](#) = 0.2 A » 0.2 Ah)

Common hourly energy draw = 9.8 Ah

Mobile solar solution

- mobile radio ([Yaesu FT-8800R](#) = 9 A, but at 50% duty cycle » 4.5 Ah)

Total mobile hourly energy draw = 9.8 Ah + 4.5 Ah = **14.3 Ah**

Portable HF solar solution

- portable HF radio ([Yaesu FT-891](#) = 23 A, but at 50% duty cycle » 11.5 Ah)
- tuner (LDG AT-100Pro II = 0.5 A » 0.5 Ah)

Total portable HF hourly energy draw = 9.8 Ah + 11.5 Ah + 0.5 Ah = **21.8 Ah**

21.8 Ah x 12 V = 261.6 Wh, which is the amount of energy you'll need, to run your portable HF station. Assuming an 80% efficient solar solution, you'll need a 261.6 Wh / 0.80 = 327 W solar panel charging your battery for an hour, or a [100 W panel](#) for about 3½ hours. A [100 Ah deep-cycle battery](#) will easily take care of these needs. If you talk less on the air (say, 25% duty cycle), you can lower those amounts to 2½ hours with the same panel into a [50 Ah battery](#).

Summary

The discussion about solar power is not a trivial one, and involves some understanding of not only how to convert radiant energy into electrical energy, but how to control it and store it. Similarly, figuring out just what it's going to take, to supply your solar needs, is also a little involved, but practical if you keep inefficiencies in mind. One final word about charge controllers: some of them tend to generate radio noise ("hash"), so keep that in mind too.

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